PATENT COOPERATION TREATY

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NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 15 November 1999 (15.11.99)	
International application No. PCT/GB99/00626	**Applicant's or agent's file reference** AA 1395 PCT
International filing date (day/month/year) 03 March 1999 (03.03.99)	**Priority date** (day/month/year) 06 March 1998 (06.03.98)
Applicant CHANDLER, Guy, Richard et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

04 October 1999 (04.10.99)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer Carlos Naranjo
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

WISHART, Ian Carmichael
Johnson Matthey Technology Centre
Blounts Court
Sonning Common
Reading RG4 9NH
GRANDE BRETAGNE

RECEIVED
12 JUN 2000

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NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT
(PCT Rule 71.1)

Date of mailing *(day/month/year)*	08.06.2000
Applicant's or agent's file reference AA 1395 PCT	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB99/00626	03/03/1999	06/03/1998

Applicant
JOHNSON MATTHEY PUBLIC LIMITED COMPANY et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/
European Patent Office
D-80298 Munich
Tel. +49 89 2399 - 0 Tx: 523656 epmu d
Fax: +49 89 2399 - 4465

Authorized officer
Ipinazar, P
Tel.+49 89 2399-8131

PATENT COOPERATION TREATY

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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
AA 1395 PCT		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB99/00626	03/03/1999	06/03/1998
International Patent Classification (IPC) or national classification and IPC B01D53/94		
Applicant JOHNSON MATTHEY PUBLIC LIMITED COMPANY et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 9 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
04/10/1999	08.06.2000
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Katsoulas, K Telephone No. +49 89 2399 8613

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB99/00626

I. Basis of the report

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

Description, pages:

1-7	as received on	10/02/2000	with letter of	07/02/2000

Claims, No.:

1-10	as received on	10/02/2000	with letter of	07/02/2000

Drawings, sheets:

1/2,2/2	as originally filed

2. The amendments have resulted in the cancellation of:

☐ the description, pages:
☐ the claims, Nos.:
☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims 1-10
	No:	Claims
Inventive step (IS)	Yes:	Claims 1-10
	No:	Claims
Industrial applicability (IA)	Yes:	Claims 1-10
	No:	Claims

2. Citations and explanations

see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Ad Section V:

1. The preamble of claim 1 is based on either EP-A-0341832 (D1) or EP-A-0758713 (D2). Both documents disclose an apparatus combining an NO_2 source and a particulate trap. Claim 1 is characterised by the provision of an exhaust gas by-pass so that a portion of the exhaust gas does not pass through the trap. By this feature, a reduction in particle collecting efficiency is compensated by the overall improved engine performance and reduced costs. Especially, the by-pass alleviates build-up of back pressure when the trap becomes clogged up. Although some (negligible) exhaust gas losses are always experienced in practice around the trap, the purposeful provision of a trap by-pass to achieve the stated advantages is considered as non-obvious in the light of the available art (Art. 33(3 PCT). This conclusion applies also to process claim 9.

Ad Section VIII:

1. In independent method claim 9, the presence of particulate matter in the emissions has been defined only as a "special" or preferable feature. This however contradicts the subsequent wording of claim 9, wherein said particulate matter is an essential feature (Art. 6 PCT).

2. Claim 8 refers to the NOx absorbent of claim 7, which in itself is an optional or preferable feature in claim 7 (Art. 6).

3. On page 2 lines 18 and 19, it is indicated that a collecting efficiency decrease of the trapping means can be effected also by "other" means, apart from by-passing the trapping means. Such a statement makes the scope of the independent claims ambiguous (Art. 6 support).

4. The embodiment according to figure 2 does not comprise a by-pass means and, as such, does not fall under the scope of the independent claims (Art. 6 support).

5. On page 3, line 5 should read: catalysts.

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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
AA 1395 PCT		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
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International Patent Classification (IPC) or national classification and IPC		
B01D53/94		
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Date of submission of the demand	Date of completion of this report
04/10/1999	08.06.2000
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Katsoulas, K Telephone No. +49 89 2399 8613

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB99/00626

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1. Statement

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	No:	Claims
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	No:	Claims

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1. In independent method claim 9, the presence of particulate matter in the emissions has been defined only as a "special" or preferable feature. This however contradicts the subsequent wording of claim 9, wherein said particulate matter is an essential feature (Art. 6 PCT).

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3. On page 2 lines 18 and 19, it is indicated that a collecting efficiency decrease of the trapping means can be effected also by "other" means, apart from by-passing the trapping means. Such a statement makes the scope of the independent claims ambiguous (Art. 6 support).

4. The embodiment according to figure 2 does not comprise a by-pass means and, as such, does not fall under the scope of the independent claims (Art. 6 support).

5. On page 3, line 5 should read: catalysts.

IMPROVEMENTS IN EMISSIONS CONTROL

The present invention concerns improvements in emission control, and more especially it concerns the control of emissions from diesel engines.

Diesel engines fall into two main categories, namely heavy duty, being principally large engines for trucks, buses and prime mover vehicle engines, ships and boats and stationary engines, and light duty engines, used in smaller trucks and cars. With the increasingly demanding regulation of emissions from all sorts of engines, attention is now being paid to control of emissions such as particulates and NOx from diesel engines. We have, in EP 341,832, described a device marketed as the Continuously Regenerating Trap ("CRT™") by Johnson Matthey. This device traps sooty particulates and causes their combustion by exposing them to NO_2 generally generated by catalytically oxidising NO present in the exhaust stream. This device has met with considerable success in controlling particulate emissions from heavy duty diesel engines, and can achieve zero emissions of particulate. That is, the CRT as marketed is approximately 100% effective to remove particulates (as defined in the regulations).

We have realised that a conventional CRT may not be cost-effective to control emissions to European Stage III, IV, or higher, regulations from light duty engines. A number of different options for controlling particulates and NOx are available, and engine manufacturers have hitherto favoured engine design and management solutions. In general, engine design itself can satisfy European Stage II emissions standards as regards NOx and particulates, but the characteristics of the diesel engine are such that engine design cannot improve upon about 0.4g/Km particulates without a serious increase in NOx, which is difficult to deal with under lean conditons. There still remains, therefore, a need for effective systems to meet these emission regulations whilst increasing engine design options.

EP 0759713 (Toyota) describes an addition to the CRT principles, involving the absorption in a NO_x absorbent of NO from gases leaving the CRT-type combination of oxidising catalyst and diesel particulate filter or trap, formed by one of the reactions of NO_2 with carbon particles.

The present invention provides an emission control exhaust gas aftertreatment apparatus for diesel engines comprising a source of NO_2, especially an oxidation catalyst effective to convert a portion of NO in the exhaust gas from said diesel engine into NO_2, and a particulate trap characterised in that an exhaust gas by-pass is provided so that a portion of the exhaust gases do not pass through the trap, such that at most 85% by weight of total engine-out particulates are collected and combusted in the presence of said NO_2 in said trap. According to various embodiments of the present invention, the quantity of particulates collected and combusted may be at most 85%, 60% or at least 50% by weight. It is, however, important that all particulates collected are combusted (over several operating cycles, but not necessarily over a single operating cycle), in order to avoid accumulation and blocking of the filter. The presence of the by-pass alleviates build-up of back pressure with consequent degradation of engine performance.

The by-pass may permit a portion of the exhaust gases to escape the trapping means either continuously or when substantial trapping of unburnt particulates has occurred. Desirably, the trapping means is designed to be "fail-safe", that is whilst it is effective to capture 50wt% or more of sooty particulates under normal conditions, the trapping means decreases its collecting efficiency whether by exhaust gases by-passing the trapping means or otherwise, if the collecting means becomes "saturated" or clogged up. This concept is, we believe, new in diesel exhaust treatment systems.

The invention accordingly provides a method of controlling emissions, especially particulate matter, from diesel engine exhaust gases by trapping and subsequently combusting said particulate matter, comprising trapping at most 85wt% of particulate matter in the presence of NO_2, and causing a portion of said exhaust gases to by-pass said particulate trapping means.

The source of NO_2 is especially conveniently an oxidation catalyst of generally known type, capable of converting at least a portion of the NO contained in diesel exhaust gases into NO_2. However, the present invention includes within its scope variations including other sources of NO_2. Such sources could include compressed NO_2, other

chemical sources which decompose or react, possibly over a catalyst, to yield NO_2, such as nitric acid, ammonia, urea, etc. The invention includes within its scope all ways of making NO_2 from the components of the exhaust gases. These may include: adding one or more catalytic components to the fuel, so that the components deposit on exhaust components including the filter; catalysing the filter or parts thereof with actalysts active at low temperatures to convert NO to NO_2; utilising a plasma to generate NO_2 by treatment of all or a portion of the exhaust gases, and other methods available to the skilled person.

In the invention, the particulate trap, or trapping means, is designed to be less than 100% effective, and desirably this brings several advantages, the first of which is considerably reduced back pressure. Light duty diesels are very much less capable of coping with back pressure from exhaust gas systems than heavy duty diesels, because they tend to be of smaller capacity and power, and in extreme cases the engine can be ruined.

The present invention is also intended to cater for some of the problems that can arise in practical usage of light duty diesels. If such engines are used in small cars or vans which are used at low speeds in towns for large portions of their operations, the exhaust gas temperature tends to be quite low, perhaps not more than 100-120°C. Under these conditions, although sooty particulates are generated in less quantities than under heavy load, the temperature is below that for the most efficient oxidation of NO to NO_2 and hence there can be insufficient NO_2, or the reaction temperature is too low for effective combustion of the sooty particles. Accordingly, for many vehicles for much of the time, the trapping means should collect sufficient of the particles to meet the emission regulations, but using a design that collects such particulates for subsequent combustion when conditions are improved, and permits the exhaust gas to pass through without excessive back pressure. In such systems, at least 50wt% of particulate matter is trapped and subsequently combusted when operating conditions in the same or subsequent operating cycles are improved.

It will be recognised that the prime purpose of the invention is to remove a proportion only of the particulates from the exhaust gas stream. This is intended to be adequate to meet the appropriate emission regulation when combined with engine design and

management improvements. The reduced efficiency in collection of particulates of the present invention brings about a significant reduction of cost, however, from a reduced volume and weight for both the catalyst and the trap compared to the state of the art CRT designed for such an engine.

The oxidation catalyst may be any that is effective to convert sufficient NO to NO_2, and is suitably a high platinum loading catalyst carried on a ceramic or metal honeycomb catalyst support. It is envisaged that in addition to reducing volume and weight of the catalyst, savings may be made in precious metal loading, thus reducing the cost yet further.

The particulate trap may suitably be a woven or knitted wire mesh or perforated metal or a suitable ceramic material. Preferred traps include especially those known as wall flow filters. The trap is suitably designed for each individual engine design, because the particulate emissions differ significantly from engine to engine. The trap may, but need not, carry a catalytic coating intended to initiate combustion at lower temperatures.

Continuing development of the inventive concept of the present invention has led to studies of flow and pressure patterns within such exhaust treatment systems. A further embodiment of the invention, in which the trap has peripheral bypass through which the exhaust gases flow only when the central portion of the trap becomes blocked, is particularly preferred. The flow of the gases can be directed to the central portion by a variety of means, including particularly baffle plates or cones, metal lips and the like, but we have found that extending the catalyst in the peripheral area is particularly simple and effective to reduce gas flow rates in that region.

A preferred embodiment of the present invention combines the emission control system with NOx control means. The NOx control may be achieved in a number of ways including exhaust gas recirculation, using a NOx conversion catalyst downstream of the trap or, more preferably, combining the trap system with a NOx absorbent. Such NOx absorbents are known to those skilled in the art and may utilise an alkaline earth metal oxide such as baria or calcia or other suitable materials. Together with the trap system of the

present invention, such an absorbent can permit extremely useful control of emissions, for example up to about 80% removal of particulates combined with up to about 80% removal of NOx. The NOx trap is desirably a single through-flow canister, which may be regenerated by periodic enrichment of the exhaust gas in a number of ways. In an even more preferred embodiment, the trap system of the invention is combined with a lean-NOx catalyst and a NOx trap. A particularly desirable embodiment is where the NOx trap is effective to trap the NOx at low temperatures and releases NOx at higher temperatures, *eg* about 250°C, at which temperatures NOx may more readily be converted and/or used in the particulate combustion of the present invention.

When using the presently-preferred platinum-based catalyst, the present invention should be used with fuel of not more than 50ppm sulphur, and preferably below 50ppm sulphur, more preferably below 10ppm sulphur. Other catalyst systems may have a wider range of fuel sulphur levels.

The invention may be better appreciated by reference to the accompanying drawings, in which:

Figure 1 is a schematic cross-section of a first embodiment of the invention,

Figure 2 is a schematic cross-section of a second embodiment of the invention, and

Figure 3 is a schematic cross-section of a further embodiment of the invention, and

Figure 4 is a schematic cross-section of a yet further embodiment.

Referring to Figure 1, a canister is to be mounted in the exhaust system of a light duty diesel, *eg* a 1.9 litre Tdi engine. The canister, 1, contains an oxidation catalyst, 2, which is a platinum catalyst carried on a 100cells/sq in metal honeycomb substrate. Particulate passes through the catalyst. A perforated gas distributor, 3, is mounted downstream of the catalyst, and surrounding the gas distributor is a sintered stainless steel filter, 4, which is located centrally within the canister. It can be seen that it is possible for the exhaust gases to by-pass the filter if the filter becomes clogged. Under ideal conditions, the filter collects sooty particles which are continuously combusted in the NO_2 generated by the catalyst, according to one or more of the equations:

$NO_2 + C \rightarrow NO + CO$

$2NO_2 + C \rightarrow 2NO + CO_2$

$2NO_2 + 2C \rightarrow N_2 + 2CO_2$

$NO_2 + O_2 + C \rightarrow 2NO + CO_2$

Under non-ideal conditions, that is at low exhaust gas temperatures, a portion only of the particulate is collected in the filter, and most of the exhaust gas by-passes the filter. Returning to higher exhaust gas temperatures permits the combustion reaction to re-start and the particulate can be totally removed from the filter.

Referring to Figure 2, an embodiment is shown which permits substantial accumulation of particulate without by-pass, but using a filter, 5, which is not 100% effective. The same items as in Figure 1 are identified using the identical reference numerals. There is sufficient capacity to accumulate particulate under all normal operating conditions.

Figure 3 utilises a slightly different by-pass design to that of the embodiment of Figure 1. The particulate is collected by impingement on a baffle plate, 6, and is shown by mass, 7. The baffle plate is itself preferably porous to gas and acts as a filter. As exhaust gas temperatures rise, the hot gases immediately contact the collected particulate and quickly cause combustion. This design may comprise electrical heating of the collection area on plate 6, creating a hot spot to initiate combustion. In a further design variation the baffle plate may comprise upstanding walls, giving a U-shaped cross-section.

A preferred embodiment is illustrated in Figure 4. Engine exhaust gas passes through catalyst 2, which is provided with a peripheral lip 2a. The resulting increased resistance to flow in the peripheral region causes the majority of the gases to flow through the central, filtering, region of trap 4, (4a) rather than through the open peripheral bypass region (4b). Thus under normal operating conditions, negligible quantities of the exhaust gases bypass the filter, but if the filter becomes blocked with particulate, the system is fail-safe and the gases bypass the filter. Surprisingly low back pressures result from this system.

The above Figure 4 embodiment was tested fitted to a commercially available 1.9 litreTdi car designed to meet European Stage II standards. After 1,000 road miles, the embodiment was tested according to the European Stage III test protocol. The following test results were obtained:

	HC (g/Km)	CO (g/Km)	NO_x (g/Km)	PM (g/Km)
Engine-out exhaust gas	0.21	0.69	0.65	0.10
With Fig 4 by-pass filter	0.02	0.03	0.62	0.02

It is to be noted that these results meet Stage IV requirements also, with the exception of NO_x. However, established engine design/management techniques can be used to lower NO_x emissions to Stage IV levels, with a consequent increase in Particulate Matter, but the system of the invention is capable of dealing with such emissions.

It will be appreciated that there are many possibilities to vary the designs shown herein without departing from the principles of the present invention.

CLAIMS

1. An emission control exhaust gas aftertreatment apparatus for exhaust gases from diesel engines, especially light duty diesel engines, comprising a source of NO_2 and a particulate trap, characterised in that an exhaust gas by-pass is provided so that a portion of the exhaust gases do not pass through the trap, such that at most 85wt% of engine-out particulates are collected on the trap and combusted in the presence of said NO_2 in said trap.

2. An apparatus according to claim 1, wherein said by-pass is effective only when substantial trapping of unburnt particulates has occurred.

3. An apparatus according to claim 1 wherein said by-pass is effective under all operating conditions and at least 50wt% of particulate matter is trapped and combusted.

4. An apparatus according to claim 2 or 3, wherein the source of NO_2 is a catalyst which is effective to convert at least a portion of the NO in the exhaust gases to NO_2

5. An apparatus according to claim 4, wherein the exhaust gases pass through the catalyst before passing through the trap.

6. An apparatus according to any one of the preceding claims, arranged such that at least 50wt% of particulate matter is trapped and subsequently combusted when operating conditions in the same or subsequent operating cycle are improved.

7. An apparatus according to any one of the preceding claims, in combination with NOx control means, preferably a NOx absorbent.

8. An apparatus according to claim 7, wherein said NOx absorbent is effective to trap NOx at relatively low exhaust gas temperatures, and releases NOx when the exhaust gas temperature exceeds about 250°C for conversion and/or consumption in the combustion of particulate matter.

9. A method of controlling emissions, especially particulate matter, from diesel engine exhaust gases by trapping and subsequently combusting said particulate matter, comprising trapping at most 85wt% of particulate matter in said exhaust gas in particulate trapping means and combusting said trapped particulate matter in the presence of NO_2 and causing a portion of said exhaust gases to by-pass said particulate trapping means.

10. A method according to claim 9, comprising using an exhaust gas by-pass such that at least 50wt% of particulate matter is collected and combusted, and the exhaust gas by-pass is effective only when there is complete or substantial blocking of the trap.

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International Bureau

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(71) Applicant *(for all designated States except US)*: JOHNSON MATTHEY PUBLIC LIMITED COMPANY [GB/GB]; 2–4 Cockspur Street, Trafalgar Square, London SW1Y 5BQ (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: CHANDLER, Guy, Richard [GB/GB]; 48 Harlton Road, Little Eversden, Cambridge CB3 7HB (GB). TWIGG, Martyn, Vincent [GB/GB]; 108 Ermine Street, Caxton, Cambridge CB3 8PQ (GB).

(74) Agent: WISHART, Ian, Carmichael; Johnson Matthey Technology Centre, Blounts Court, Sonning Common, Reading RG4 9NH (GB).

(81) Designated States: CA, JP, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

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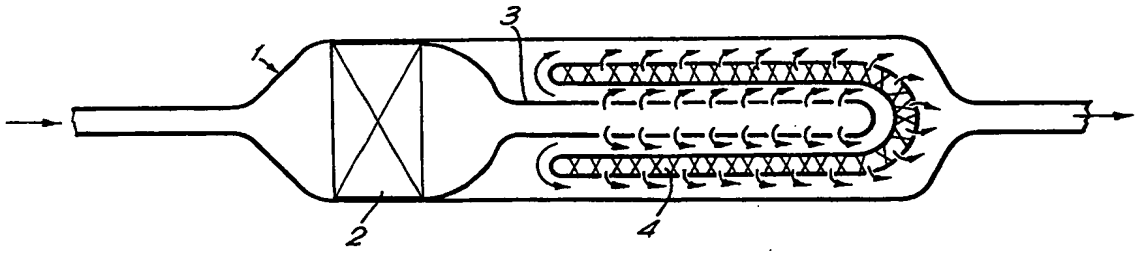

(57) Abstract

A cost–effective solution to removing particulates from diesel, especially light–duty diesel engines incorporates an oxidation catalyst (2) effective to convert NO in the exhaust from the engine to NO_2 and a particulate trap (4) which traps no more than 85 % by weight of the particulate, optionally by permitting gas to by–pass the trap.

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IMPROVEMENTS IN EMISSIONS CONTROL

The present invention concerns improvements in emission control, and more especially it concerns the control of emissions from diesel engines.

Diesel engines fall into two main categories, namely heavy duty, being principally large engines for trucks, buses and prime mover vehicle engines, ships and boats and stationary engines, and light duty engines, used in smaller trucks and cars. With the increasingly demanding regulation of emissions from all sorts of engines, attention is now being paid to control of emissions such as particulates and NOx from diesel engines. We have, in EP 341,832, described a device marketed as the Continuously Regenerating Trap ("CRT™") by Johnson Matthey. This device traps sooty particulates and causes their combustion by exposing them to NO_2 generally generated by catalytically oxidising NO present in the exhaust stream. This device has met with considerable success in controlling particulate emissions from heavy duty diesel engines, and can achieve zero emissions of particulate. That is, the CRT as marketed is approximately 100% effective to remove particulates (as defined in the regulations).

We have realised that a conventional CRT may not be cost-effective to control emissions to European Stage III, IV, or higher, regulations from light duty engines. A number of different options for controlling particulates and NOx are available, and engine manufacturers have hitherto favoured engine design and management solutions. In general, engine design itself can satisfy European Stage II emissions standards as regards NOx and particulates, but the characteristics of the diesel engine are such that engine design cannot improve upon about 0.4g/Km particulates without a serious increase in NOx, which is difficult to deal with under lean conditons. There still remains, therefore, a need for effective systems to meet these emission regulations whilst increasing engine design options.

The present invention provides an emission control system for diesel engines comprising a source of NO_2, especially an oxidation catalyst effective to convert a portion of NO in the exhaust gas from said diesel engine into NO_2, and a particulate trap characterised in that at most 85% by weight of total engine-out particulates are collected and

combusted in the presence of said NO_2 in said trap. According to various embodiments of the present invention, the quantity of particulates collected and combusted may be at most 85%, 60% or at most 50% by weight. It is, however, important that all particulates collected are combusted (over several operating cycles, but not necessarily over a single operating cycle), in order to avoid accumulation and blocking of the filter, causing build-up of back pressure with consequent degradation of engine performance.

Another embodiment of the present invention comprises an oxidation catalyst effective to convert a portion of NO in the exhaust gas into NO_2, or other source of NO_2, and particle trapping means which means permits a portion of the exhaust gases to escape the trapping means. Desirably, the trapping means is designed to be "fail-safe", that is whilst it is effective to capture 50wt% or more of sooty particulates under normal conditions, the trapping means decreases its collecting efficiency whether by exhaust by-passing the trapping means or otherwise, if the collecting means becomes "saturated" or clogged up. This concept is, we believe, new in diesel exhaust treatment systems.

The invention further provides a method for the control of at least sooty particulates from diesel engine exhausts by trapping and subsequently combusting said particulates by reaction with NO_2, characterised in that at most 85wt% of the particulates are trapped for subsequent combustion.

The source of NO_2 is especially conveniently an oxidation catalyst of generally known type, capable of converting at least a portion of the NO contained in diesel exhaust gases into NO_2. However, the present invention includes within its scope variations including other sources of NO_2. Such sources could include compressed NO_2, other chemical sources which decompose or react, possibly over a catalyst, to yield NO_2, such as nitric acid, ammonia, urea, etc. The invention includes within its scope all ways of making NO_2 from the components of the exhaust gases. These may include: adding one or more catalytic components to the fuel, so that the components deposit on exhaust components including the filter; catalysing the filter or parts thereof with actalysts active at low

temperatures to convert NO to NO_2; utilising a plasma to generate NO_2 by treatment of all or a portion of the exhaust gases, and other methods available to the skilled person.

In the invention, the particulate trap, or trapping means, is designed to be less than 100% effective, and desirably this brings several advantages, the first of which is considerably reduced back pressure. Light duty diesels are very much less capable of coping with back pressure from exhaust gas systems than heavy duty diesels, because they tend to be of smaller capacity and power, and in extreme cases the engine can be ruined.

The present invention is also intended to cater for some of the problems that can arise in practical usage of light duty diesels. If such engines are used in small cars or vans which are used at low speeds in towns for large portions of their operations, the exhaust gas temperature tends to be quite low, perhaps not more than 100-120°C. Under these conditions, although sooty particulates are generated in less quantities than under heavy load, the temperature is below that for the most efficient oxidation of NO to NO_2 and hence there can be insufficient NO_2, or the reaction temperature is too low for effective combustion of the sooty particles. Accordingly, for many vehicles for much of the time, the trapping means should collect sufficient of the particles to meet the emission regulations, but using a design that collects such particulates for subsequent combustion when conditions are improved, and permits the exhaust gas to pass through without excessive back pressure. In such systems, at least 50wt% of particulate matter is trapped and subsequently combusted when operating conditions in the same or subsequent operating cycles are improved.

It will be recognised that the prime purpose of the invention is to remove a proportion only of the particulates from the exhaust gas stream. This is intended to be adequate to meet the appropriate emission regulation when combined with engine design and management improvements. The reduced efficiency in collection of particulates of the present invention brings about a significant reduction of cost, however, from a reduced volume and weight for both the catalyst and the trap compared to the state of the art CRT designed for such an engine.

The oxidation catalyst may be any that is effective to convert sufficient NO to NO_2, and is suitably a high platinum loading catalyst carried on a ceramic or metal honeycomb catalyst support. It is envisaged that in addition to reducing volume and weight of the catalyst, savings may be made in precious metal loading, thus reducing the cost yet further.

The particulate trap may suitably be a woven or knitted wire mesh or perforated metal or a suitable ceramic material. Preferred traps include especially those known as wall flow filters. The trap is suitably designed for each individual engine design, because the particulate emissions differ significantly from engine to engine. The trap may, but need not, carry a catalytic coating intended to initiate combustion at lower temperatures.

Continuing development of the inventive concept of the present invention has led to studies of flow and pressure patterns within such exhaust treatment systems. A further embodiment of the invention, in which the trap has peripheral bypass through which the exhaust gases flow only when the central portion of the trap becomes blocked, is particularly preferred. The flow of the gases can be directed to the central portion by a variety of means, including particularly baffle plates or cones, metal lips and the like, but we have found that extending the catalyst in the peripheral area is particularly simple and effective to reduce gas flow rates in that region.

A preferred embodiment of the present invention combines the emission control system with NOx control means. The NOx control may be achieved in a number of ways including exhaust gas recirculation, using a NOx conversion catalyst downstream of the trap or, more preferably, combining the trap system with a NOx absorbent. Such NOx absorbents are known to those skilled in the art and may utilise an alkaline earth metal oxide such as baria or calcia or other suitable materials. Together with the trap system of the present invention, such an absorbent can permit extremely useful control of emissions, for example up to about 80% removal of particulates combined with up to about 80% removal of NOx. The NOx trap is desirably a single through-flow canister, which may be regenerated by periodic enrichment of the exhaust gas in a number of ways. In an even more preferred embodiment, the trap system of the invention is combined with a lean-NOx

catalyst and a NOx trap. A particularly desirable embodiment is where the NOx trap is effective to trap the NOx at low temperatures and releases NOx at higher temperatures, *eg* about 250°C, at which temperatures NOx may more readily be converted and/or used in the particulate combustion of the present invention.

When using the presently-preferred platinum-based catalyst, the present invention should be used with fuel of not more than 50ppm sulphur, and preferably below 50ppm sulphur, more preferably below 10ppm sulphur. Other catalyst systems may have a wider range of fuel sulphur levels.

The invention may be better appreciated by reference to the accompanying drawings, in which:

Figure 1 is a schematic cross-section of a first embodiment of the invention,

Figure 2 is a schematic cross-section of a second embodiment of the invention, and

Figure 3 is a schematic cross-section of a further embodiment of the invention, and

Figure 4 is a schematic cross-section of a yet further embodiment.

Referring to Figure 1, a canister is to be mounted in the exhaust system of a light duty diesel, *eg* a 1.9 litre Tdi engine. The canister, 1, contains an oxidation catalyst, 2, which is a platinum catalyst carried on a 100cells/sq in metal honeycomb substrate. Particulate passes through the catalyst. A perforated gas distributor, 3, is mounted downstream of the catalyst, and surrounding the gas distributor is a sintered stainless steel filter, 4, which is located centrally within the canister. It can be seen that it is possible for the exhaust gases to by-pass the filter if the filter becomes clogged. Under ideal conditions, the filter collects sooty particles which are continuously combusted in the NO_2 generated by the catalyst, according to one or more of the equations:

$$NO_2 + C \rightarrow NO + CO$$

$$2NO_2 + C \rightarrow 2NO + CO_2$$

$$2NO_2 + 2C \rightarrow N_2 + 2CO_2$$

$$NO_2 + O_2 + C \rightarrow 2NO + CO_2$$

Under non-ideal conditions, that is at low exhaust gas temperatures, a portion only of the particulate is collected in the filter, and most of the exhaust gas by-passes the filter. Returning to higher exhaust gas temperatures permits the combustion reaction to re-start and the particulate can be totally removed from the filter.

Referring to Figure 2, an embodiment is shown which permits substantial accumulation of particulate without by-pass, but using a filter, 5, which is not 100% effective. The same items as in Figure 1 are identified using the identical reference numerals. There is sufficient capacity to accumulate particulate under all normal operating conditions.

Figure 3 utilises a slightly different by-pass design to that of the embodiment of Figure 1. The particulate is collected by impingement on a baffle plate, 6, and is shown by mass, 7. The baffle plate may itself be porous to gas or act as a filter. As exhaust gas temperatures rise, the hot gases immediately contact the collected particulate and quickly cause combustion. This design may comprise electrical heating of the collection area on plate 6, creating a hot spot to initiate combustion. In a further design variation the baffle plate may comprise upstanding walls, giving a U-shaped cross-section.

A preferred embodiment is illustrated in Figure 4. Engine exhaust gas passes through catalyst 2, which is provided with a peripheral lip 2a. The resulting increased resistance to flow in the peripheral region causes the majority of the gases to flow through the central, filtering, region of trap 4, (4a) rather than through the open peripheral bypass region (4b). Thus under normal operating conditions, negligable quantities of the exhaust gases bypass the filter, but if the filter becomes blocked with particulate, the system is fail-safe and the gases bypass the filter. Surprisingly low back pressures result from this system.

The above Figure 4 embodiment was tested fitted to a commercially available 1.9 litreTdi car designed to meet European Stage II standards. After 1,000 road miles, the embodiment was tested according to the European Stage III test protocol. The following test results were obtained:

	HC (g/Km)	CO (g/Km)	NO_x (g/Km)	PM (g/Km)
Engine-out exhaust gas	0.21	0.69	0.65	0.10
With Fig 4 by-pass filter	0.02	0.03	0.62	0.02

It is to be noted that these results meet Stage IV requirements also, with the exception of NO_x. However, established engine design/management techniques can be used to lower NO_x emissions to Stage IV levels, with a consequent increase in Particulate Matter, but the system of the invention is capable of dealing with such emissions.

It will be appreciated that there are many possibilities to vary the designs shown herein without departing from the principles of the present invention.

CLAIMS

1. An emission control system for exhaust gases from diesel engines, especially light duty diesel engines, comprising a source of NO_2 and a particulate trap, characterised in that at most 85wt% of engine-out particulates are collected on the trap and combusted in the presence of said NO_2 in said trap.

2. A system according to claim 1, wherein the source of NO_2 is a catalyst which is effective to convert at least a portion of the NO in the exhaust gases to NO_2

3. A system according to claim 2, wherein the exhaust gases pass through the catalyst before passing through the trap.

4. A system according to claim 1, 2 or 3 wherein an exhaust gas by-pass is provided so that a portion of the exhaust gas does not pass through the filter.

5. A system according to claim 4, wherein said by-pass is effective only when substantial trapping of unburnt particulates has occurred.

6. A system according to claim 4 wherein said by-pass is effective under all operating conditions and at least 50wt% of particulate matter is trapped and combusted.

7. A system according to any one of the preceding claims, arranged such that at least 50wt% of particulate matter is trapped and subsequently combusted when operating conditions in the same or subsequent operating cycle are improved.

8. A system according to any one of the preceding claims, in combination with NOx control means.

9. A system according to claim 8, wherein the NOx control means comprises a NOx absorbent.

10. A system according to claim 9, wherein said NOx absorbent is effective to trap NOx at relatively low exhaust gas temperatures, and releases NOx when the exhaust gas temperature exceeds about 250°C for conversion and/or consumption in the combustion of particulate matter.

11. A method of controlling emissions, especially particulate matter, from diesel engine exhaust gases by trapping and subsequently combusting said particulate matter, comprising trapping at most 85wt% of particulate matter in said exhaust gas and combusting said trapped particulate matter in the presence of NO_2.

12. A method according to claim 11, comprising using an exhaust gas by-pass such that at least 50wt% of particulate matter is collected and combusted, and the exhaust gas by-pass is effective only when there is complete or substantial blocking of the trap.

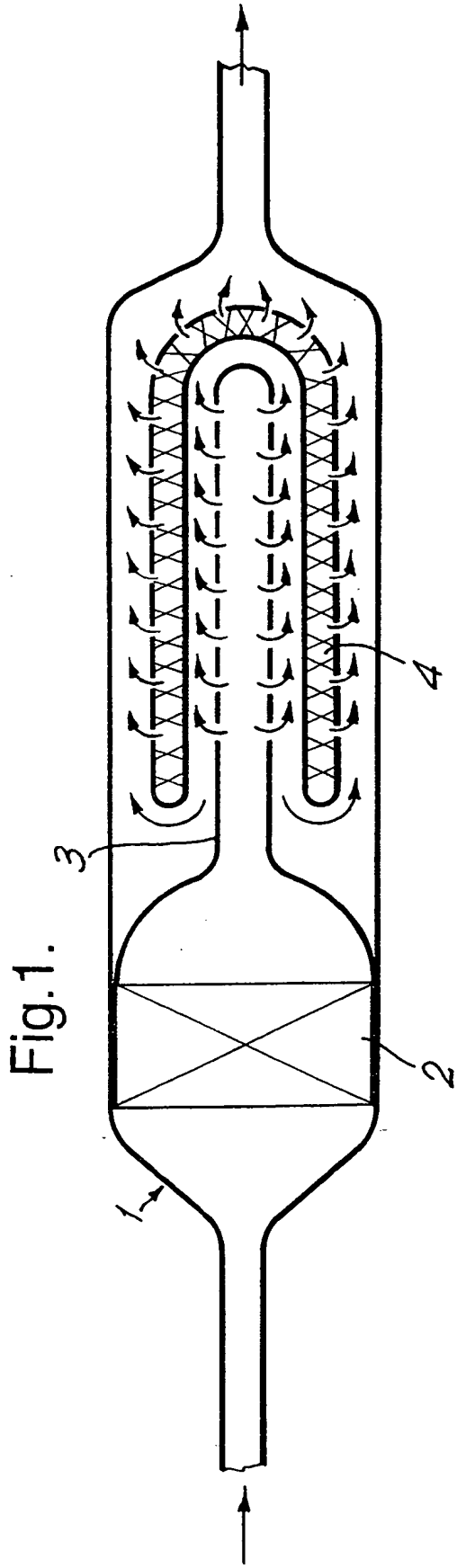

Fig.1.

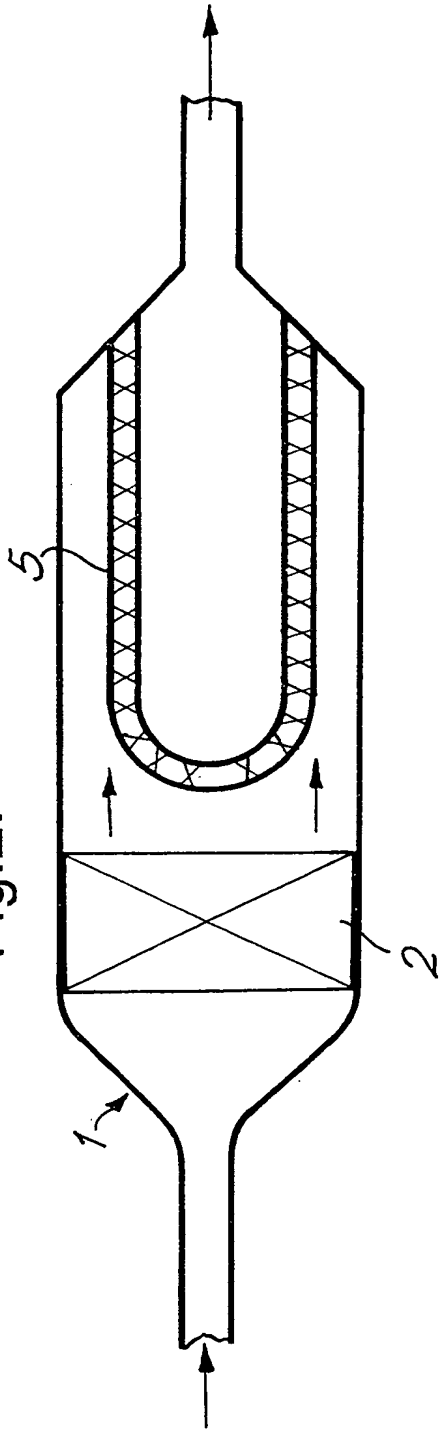

Fig.2.

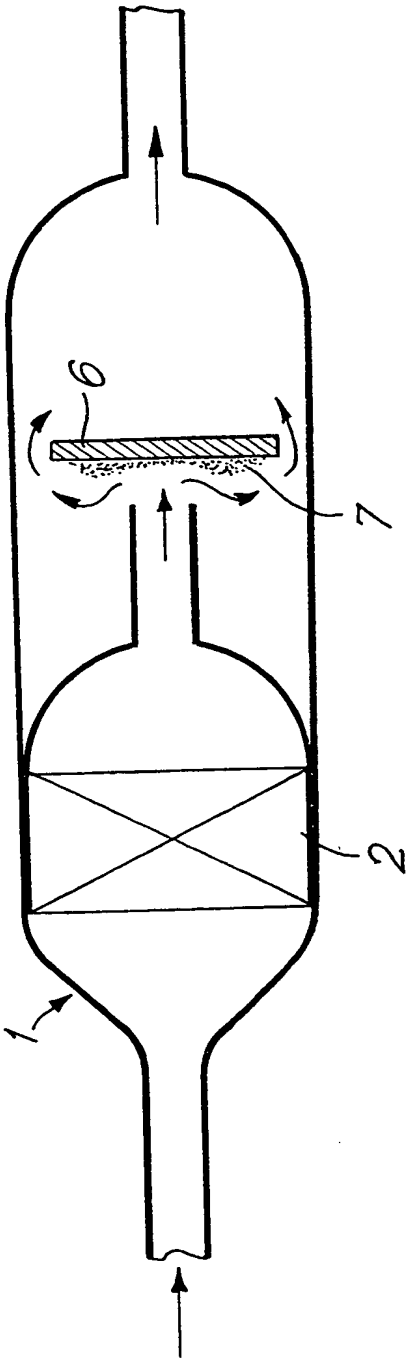

Fig.3.

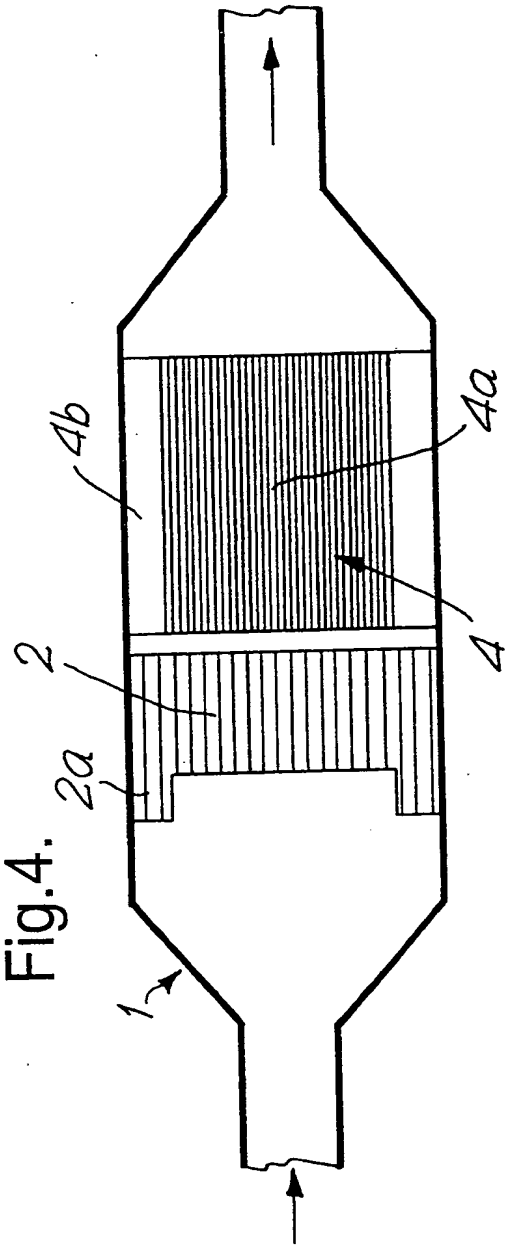

Fig.4.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 99/00626

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B01D53/94 F01N3/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B01D F01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 758 713 A (TOYOTA MOTOR CO LTD) 19 February 1997 see column 2, line 41 - column 3, line 22	1-3,8-10
X	EP 0 341 832 A (JOHNSON MATTHEY INC) 15 November 1989 cited in the application see page 2, line 43 - line 51	1-3,11
A	DE 33 37 903 A (REIF GERHARD;BAUM WERNER) 9 May 1985 see figure 1	1,2,11

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
8 June 1999	16/06/1999

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

...rmation on patent family members

International Application No
PCT/GB 99/00626

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